



## Tuning the Ground State of Oxide Interfaces by an Electron Sink

**Gan, Y. L.; von Soosten, M.; Zhang, Y. ; Krishnan, D. ; Zhong, Z. ; Niu, W.; Carrad, D. J.; Norrman, K.; Christensen, D. V.; Gauquelin, N.**

*Total number of authors:*

16

*Publication date:*

2018

*Document Version*

Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*

Gan, Y. L., von Soosten, M., Zhang, Y., Krishnan, D., Zhong, Z., Niu, W., Carrad, D. J., Norrman, K., Christensen, D. V., Gauquelin, N., Jespersen, T. S., Shen, B. G., Verbeeck, J., Sun, J. R., Pryds, N., & Chen, Y. Z. (2018). *Tuning the Ground State of Oxide Interfaces by an Electron Sink*. Abstract from 25th International Workshop on Oxide Electronics, Les Diablerets, Switzerland.

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

## Tuning the Ground State of Oxide Interfaces by an Electron Sink

Y. L. Gan<sup>1</sup>, M. von Soosten<sup>1,2</sup>, Y. Zhang<sup>1,3</sup>, H. R. Zhang<sup>3</sup>, D. Krishnan<sup>4</sup>, Z. Zhong<sup>5</sup>, W. Niu<sup>1</sup>, D. J. Carrad<sup>2</sup>, K. Norrman<sup>1</sup>, D. V. Christensen<sup>1</sup>, N. Gauquelin<sup>4</sup>, T. S. Jespersen<sup>2</sup>, B. G. Shen<sup>3</sup>, J. Verbeeck<sup>4</sup>, J. R. Sun<sup>3</sup>, N. Pryds<sup>1</sup> and Y. Z. Chen<sup>1\*</sup>

<sup>1</sup>Department of Energy Conversion and Storage, Technical University of Denmark, Risø Campus, 4000 Roskilde, Denmark

<sup>2</sup>Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark

<sup>3</sup>National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

<sup>4</sup>EMAT, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium.

<sup>5</sup>Key Laboratory of Magnetic Materials and Devices, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, 315201, China

\*E-mail: [yuga@dtu.dk](mailto:yuga@dtu.dk); [yunc@dtu.dk](mailto:yunc@dtu.dk);

**Preferred Type of Presentation:** ☐ Oral ☒ Poster

The two-dimensional electron liquid (2DEL) formed at the LaAlO<sub>3</sub>/SrTiO<sub>3</sub> (LAO/STO) interface is related to the electrons located in 3d-orbit of Ti. Due to electron-electron interactions, the ground state of the system, which is either superconducting or magnetic, is sensitive to external electric field that changes the carrier density by tuning the shape and width of the potential well [1]. On the other hand, a charge-transfer-induced modulation doping can be made by inserting a LaMnO<sub>3</sub>(LMO) buffer layer into LAO/STO interface which not only significantly suppresses the carrier density but also boosts the mobility of these carriers [2]. Herein, we report unforeseen tunability of the phase diagram of the metallic LAO/STO interface by introducing an electron sink of ferromagnetic LaMnO<sub>3</sub> insulator into the LAO side. This is done without formation of lattice disorder and without changing the polarity of the system, LaAl<sub>1-x</sub>Mn<sub>x</sub>O<sub>3</sub>/STO (0 ≤ x ≤ 1). By deliberately increasing the Mn-doping level, x, the interfacial 2DEL undergoes a Lifshitz transition [3] at x = 0.225 with a critical carrier density of  $n_c = 2.8 \times 10^{13} \text{ cm}^{-2}$ , where a peak value of ~250 mK of superconducting transition temperature is observed. Moreover, the LaAl<sub>1-x</sub>Mn<sub>x</sub>O<sub>3</sub> turns ferromagnetic at x ≥ 0.25. Remarkably, at a doping level of x = 0.3, just before the metallic interface becomes insulating, we observed signatures of both ferromagnetism and superconductivity in the same 2DEL where the  $d_{xy}$  electrons is dominated.

### References:

1. A. E. M. Smink, J. C. de Boer, M. P. Stehno, A. Brinkman, W. G. van der Wiel and H. Hilgenkamp, Gate-Tunable Band Structure of the LaAlO<sub>3</sub>-SrTiO<sub>3</sub> Interface, PRL. 118 (2017) 106401. DOI: 10.1103/PhysRevLett.118.106401
2. Y. Z. Chen et al. Extreme mobility enhancement of two dimensional electron gases at oxide interfaces by charge-transfer-induced modulation doping, Nature Mater. (2015) 14, 801-806. DOI: 10.1038/NMAT4303
3. Arjun Joshua, S. Pecker, J. Ruhman, E. Altman and S. Ilani, A universal critical density underlying the physics of electrons at the LaAlO<sub>3</sub>/SrTiO<sub>3</sub> interface. Nat. Commun. (2012) 3:1129. DOI: 10.1038/ncomms2116.